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Welcome!

The program will begin soon.

You will not hear audio until we begin.

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Protect Wells During Frac Plug Drillouts and Well Flowback Operations using Multiphase Flow Meters

Presented by: Katharine Moncada

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Agenda

- Venturi/gamma-ray multiphase flow meter (MPFM) technology
  - Principle of measurement
  - Applications
- Well start up operations
  - Frac plug drill outs and well flowback operations
- Venturi/gamma-ray technology adaptation to measure sand
  - Field examples

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Venturi/Gamma-ray or Vx MPFM: Sensors

- The raw measurements used for multiphase flow metering using Vx technology are:
  - **V**: pressure differential across the Venturi
  - **X**: full gamma-ray spectroscopy
  - Pressure at line conditions
  - Temperature at line conditions

- All sensors except the temperature sensor are located at the throat of the venturi section

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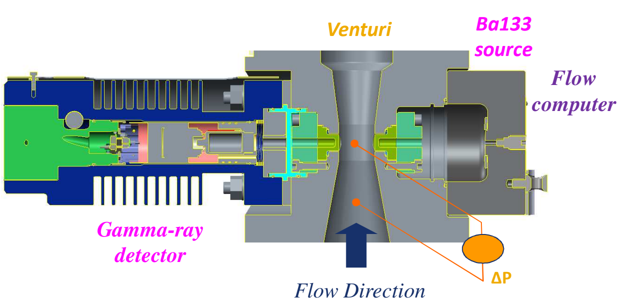
Vx MPFM Technology

Three distinct sections:



Fluid Mechanics – Flow Model
→ Total Mass Flow Rate (Bernoulli)

Nuclear Physics – Nuclear Model
→ 3 Phase Fractions (Nuclear Equations)

Fluid Behavior – PVT Model
→ Convert from Line to Standard Conditions

Single-point measurement at the venturi throat at **high frequency** and **independent of flow regimes**

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Total Mass Flow Rate & Fraction Calculation

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Flow Model

$$Q_{TotalMass} = K\sqrt{2\rho_{mix}\Delta P_{dyn}}$$

Nuclear Model

3 equations with 3 unknowns

$$N^{le} = N_0^{le} e^{-D\left[\mu_o^{le}.\rho_o.\alpha_o + \mu_w^{le}.\rho_w.\alpha_w + \mu_g^{le}.\rho_g.\alpha_g\right]}$$

$$N^{he} = N_0^{he} e^{-D\left[\mu_o^{he}.\rho_o.\alpha_o + \mu_w^{he}.\rho_w.\alpha_w + \mu_g^{he}.\rho_g.\alpha_g\right]}$$

$$\alpha_o + \alpha_w + \alpha_g = 1$$

PVT Model (Black Oil Model): Oil, Gas, Water Volumetric Flowrates Outputs at Standard Conditions

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Phase Measurements Mechanism

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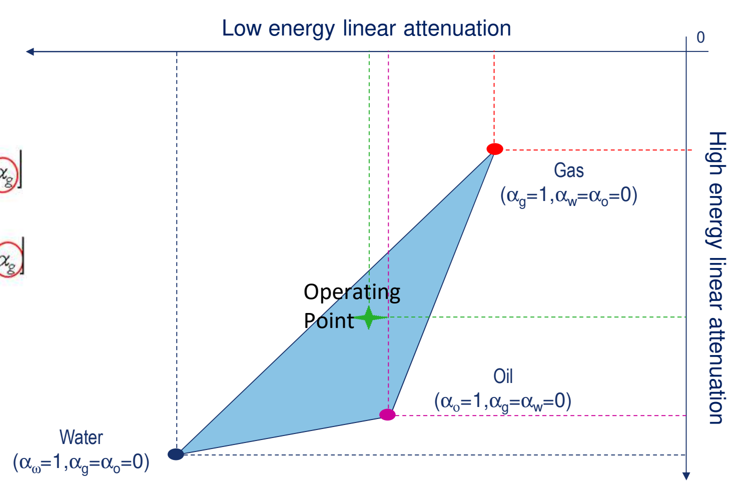
$$\alpha_o + \alpha_w + \alpha_g = 1$$

$$N^{le} = N_0^{le} e^{-D\left[\mu_o^{le}.\rho_o.\alpha_o + \mu_w^{le}.\rho_w.\alpha_w + \mu_g^{le}.\rho_g.\alpha_g\right]}$$

$$N^{he} = N_0^{he} e^{-D\left[\mu_o^{he}.\rho_o.\alpha_o + \mu_w^{he}.\rho_w.\alpha_w + \mu_g^{he}.\rho_g.\alpha_g\right]}$$

$$\rho_{mix} = \alpha_o\rho_o + \alpha_w\rho_w + \alpha_g\rho_g$$



Linear Attn = Mass Attn (Composition) x Density (P, T)

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Vx MPFM Typical Applications

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- Production reporting
  - Production allocation (partners, cross border)
  - Taxes
  - Accounting
- Assets management and reservoir monitoring
- Operations planning
- Environmental regulations
- Well production optimization: ESP, gas lift, choke optimization

Permanent Vx MPFM for production monitoring

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Vx MPFM Additional Applications

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For harsh/erosive environments

- Post-frac well start up operations
  - Coil tubing (CT) plug drill outs operations
  - Flowback and cleanup operations

Mobile Vx MPFM for production testing

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Post-Frac Well Start Up Operations

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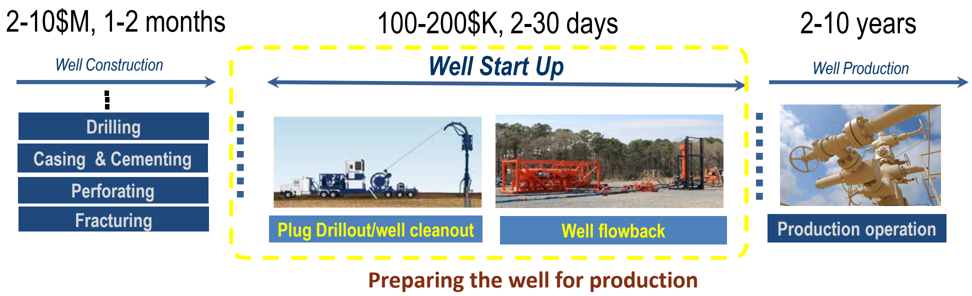

Importance of a good operation

- Protection of invest (Production decrease: up to 50%)
- Minimize sand flowback (i.e 200-300Klb of proppant/well wasted up to 5% of well cost)

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Post-frac Well Start Up - Potentially a Flash Flooding Event!

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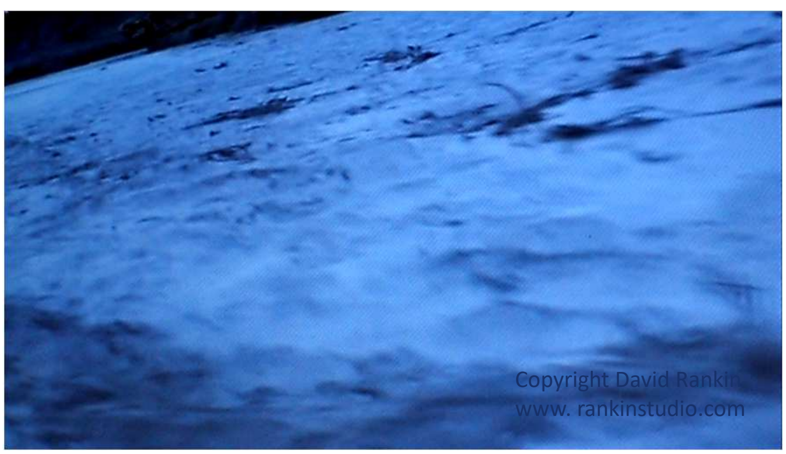

(18) September 9th, 2013. Flash Flood Footage / Erosion Shots Utah Monsoon - YouTube

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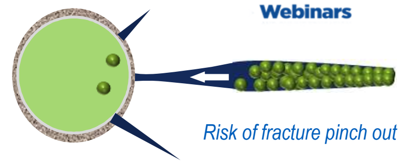
Fracture Damage Mechanisms

- Uncontrolled Sand Flowback / Fracture Closure
  - Proppant flowback results in unpropped area at NWB (near-wellbore) zone
  - Risk of pinch-point / closure in unpropped area
  - Sand inside tubulars causes additional resistance to flow (smaller ID)
  - Significant portion of sand flowback occurs during plug drill-out
- Rock Failure
  - Excessive drawdown rates may cause formation rock failure and fracture plugging
- Scaling / Precipitation
  - Reduction in hydraulic fracture conductivity
  - Negative impact on outflow performance
  - Surface equipment issues



Risk of fracture pinch out

Risk of formation rock failure

Risk of scale formation

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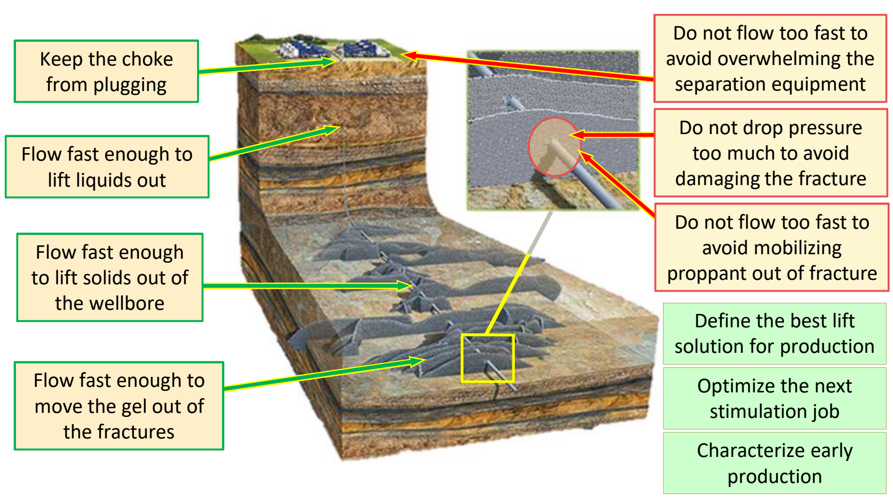
Fracture Plug Drill-out and Well Flowback Considerations



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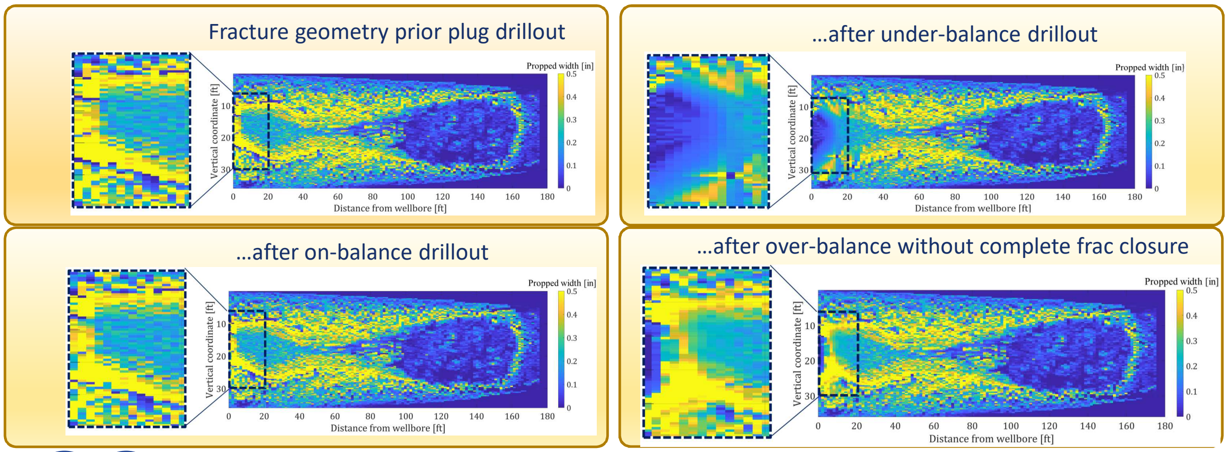
Proppant Stability Modeling Study During Plug DrillOut



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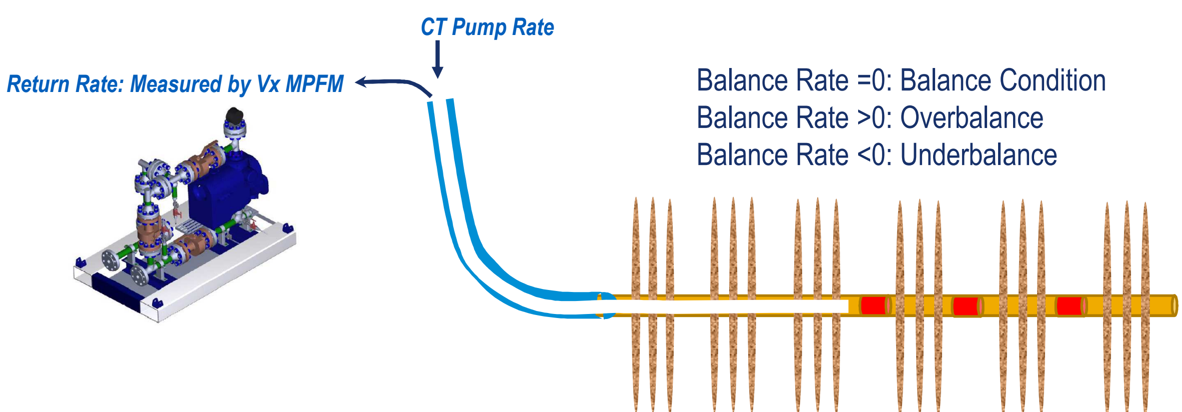
Plug DrillOut (PDO) Operation: Return Rate and Well Balance



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Plug DrillOut (PDO) Operation: Example

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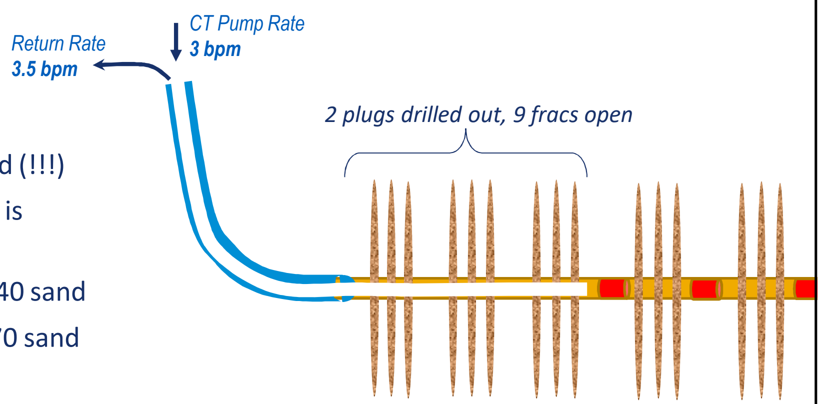
- ~0.5 bpm is produced
- from 9 fracs
- 0.5 bpm = 720 bpd
- Rate per fracture: 720/9=80bpd (!!!)
- For comparison proppant pack is stable until
  - ~20bpd per fracture for 20/40 sand
  - ~10bpd per fracture for 40/70 sand



A significant portion of the sand flowback occurs during plug drill-out, that could affect fracture stability

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Using Vx MPFM Technology to Minimize Risk During PDO

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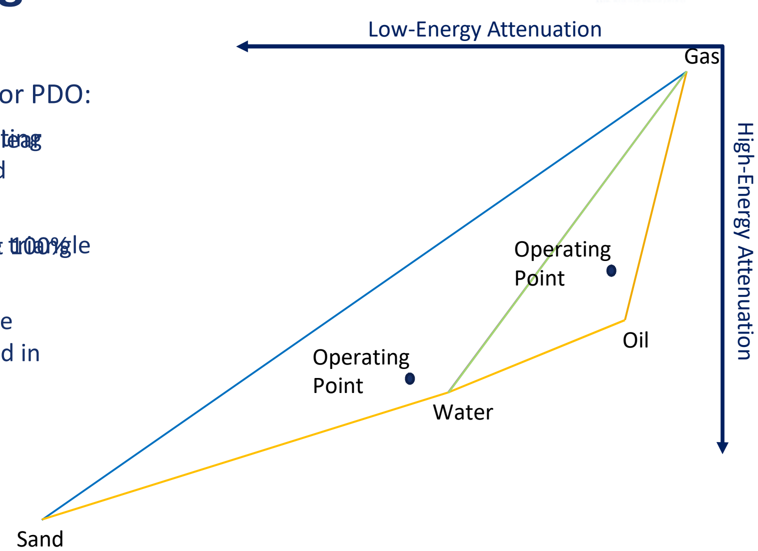
How does it quantify sand fractions for PDO:

- Phase fractions are derived from nuclear model and the operating triangle
- Sand quantification uses same operating triangle principle as three phase fluid measurement
- The three points of the triangle are calibrated to the GR measurement at 100% of the given fluid
- This third phase is represented by the triangle of the new Gas, Sand, and Water
- The operating point will represent the instantaneous measurement of a fluid in the venturi throat



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Plug DrillOut (PDO) Operation: Real-time Control

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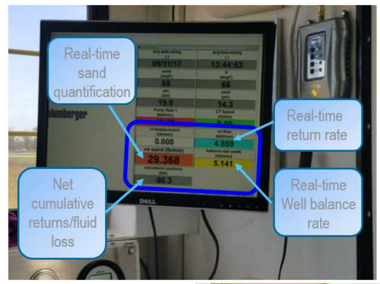
- "Must-have" real-time well operational control
- Developed, verified and implemented for SLB CT or other providers

Enables:

- Real-time control of fluid return **(Operational efficiency)**
  - Better clean out, reduced NPT (i.e CT getting stuck)
- Real-time
  - solids monitoring **(fracture protection)**
  - Gas emissions monitoring
- **Quantitative control of well balance conditions**
  - Over, under, on-balance



Vx MFPM data - Monitor @ CT Unit

Vx MPFM supporting a PDO operation

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Vx Meter Rig up for CT Plug Drill Out Eagle Ford Shale

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Example 1: Enables Sand Measurement at Surface

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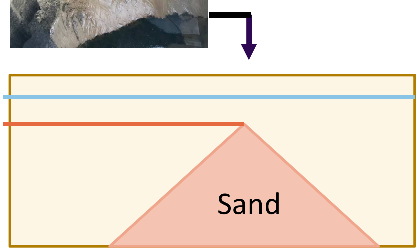
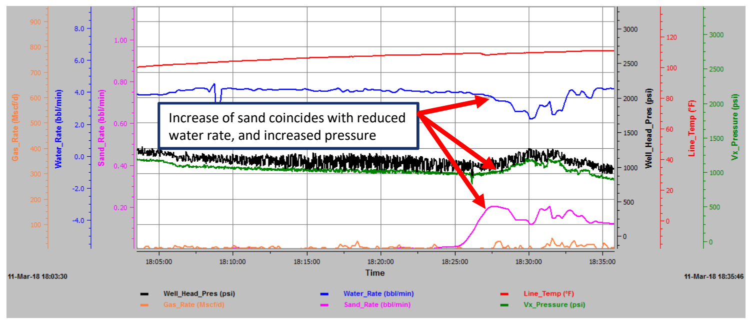
- Straps can be highly inaccurate when sand accumulates at bottom of tanks
- Vx rates not affected by tank volume
- Vx quantifies return rates as well as total sand volume in tank



Sand pit

Vx MFPM helps detect sand slugs gets pushed to surface



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Example 2: Enhances Detection of Erode Chokes

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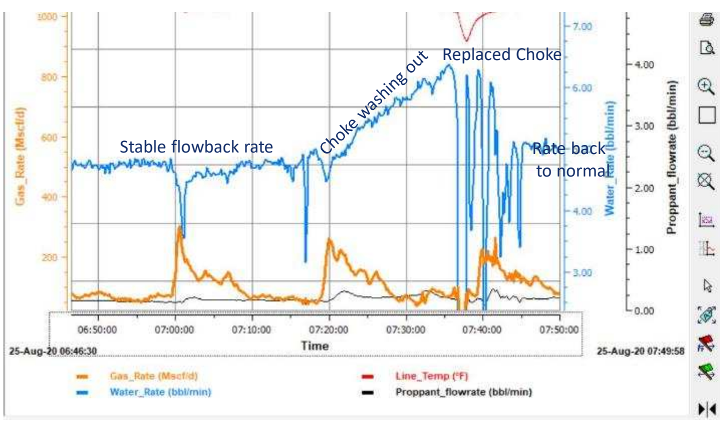
Vx MFPM helps detect choke washed out on manifold



Eroded choke needle

Washed out choke bean

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Example 3: Provides Data to Evaluate PDO Efficiency

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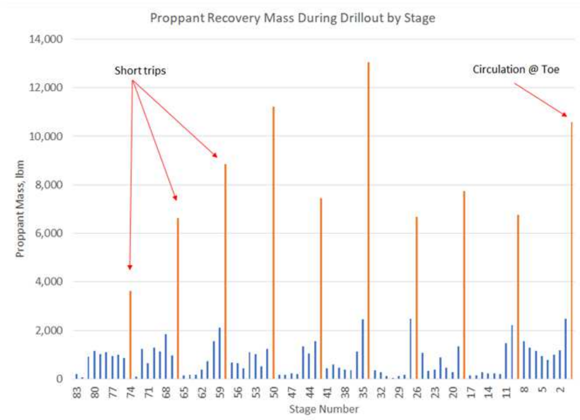
Vx MFPM measures sand recovery during plug drillout



- Plug drillouts often include short trips to keep from getting stuck
- Short trip recoveries suggest inefficient sand transport

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Flowback and Choke Management Strategy – Impact on Production

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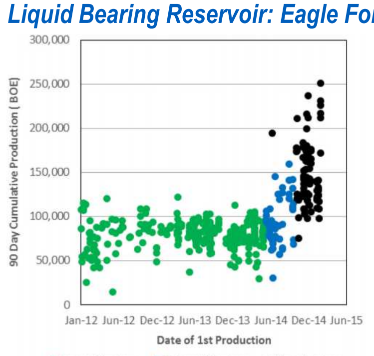
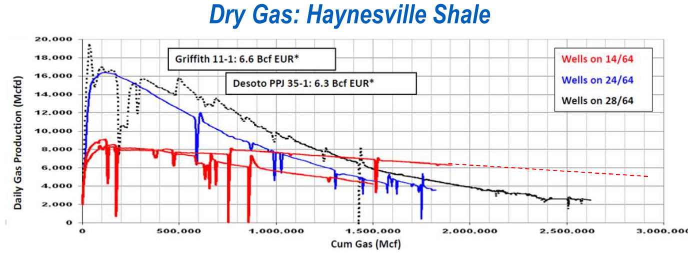
Liquid Bearing Reservoir: Eagle Ford



SPE-174831, 2015

Dry Gas: Haynesville Shale



http://www.haynesvilleplay.com/2010/05/petrohawk-analyst-day-part-two.html

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Excessive proppant flowback results in unpropped areas near wellbore

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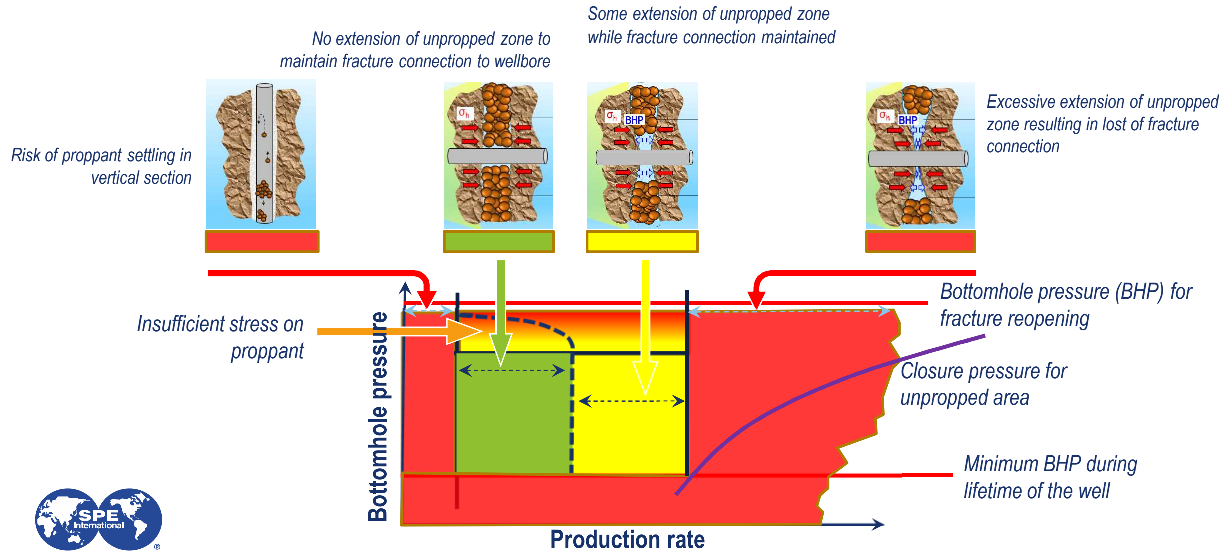
Secure Operating Envelope (SOE)



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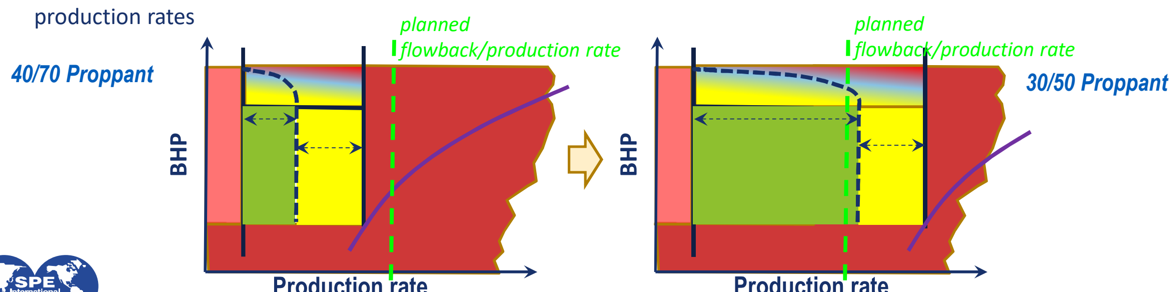
SOE & Pre-completion Analysis

- Maximizing well productivity through ensuring frac stability
- Pre-completion analysis is critical
  - Ensuring "compatibility" between well completion plan, plan for post-stimulation operations and planned production rate
  - Using SOE to understand ability of fracture to "survive" planned production
  - Adjustments to tail-in state of fracture treatment if needed for extending SOE to the range of considered production rates



http://www.slb.com/avantguard

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Case Study: Improve Flowback Process, Powder River Basin

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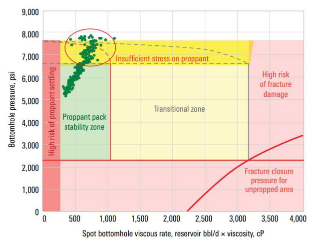
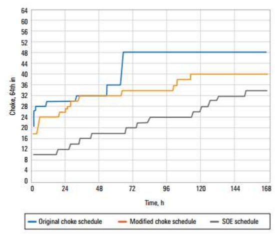
Step 1. SOE Analysis

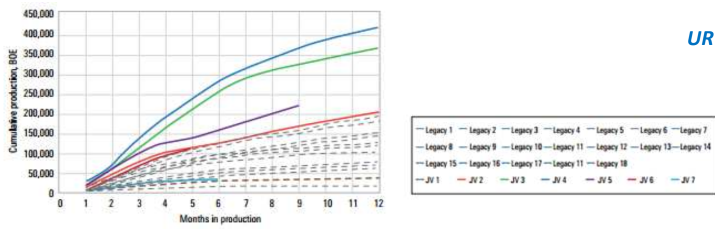


Step 2. Optimized Choke strategy



- Legacy wells in Powder River Basin were producing 80,000 lbm sand per well.
- Post mortem analysis showed that wells were being flowed too aggressively, too early.
- Modifications to the choke management strategy resulted in better productivity and only 30 lbm sand per well.

Step 3. Corroborate results with production data



URTeC-2019-285-MS

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Track Record

- Utilized in Haynesville, DJ, Marcellus, Permian & Eagle Ford
- Reduced HSE Risk
- Track record of success with zero stuck events on over 400+ wells
- SLB MPFM combined experience >20 years

Benefits

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- 10-20% reduction in mill out time using real time data
- Avoid fracture damage while maximizing well productivity
- Real time quantification of flow rates, sand & emissions

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Case Studies

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- SPE-187104-MS Securing Long Term Well Productivity of Horizontal Wells
- SPE-196084-MS State of the Art of Flow Management for Frac Plug Drillout and Flowback
- SPE 6813-MS Proppant Transport
- Public SLB.com Case Studies found at: http://www.slb.com/avantguard
  - AvantGuard Advanced Flowback Services Help Lonestar Determine Optimal Coiled Tubing Operating Conditions
  - Vx Spectra flowmeter Enables Real-Time Sand Quantification During Drillout in the Eagle Ford Shale
  - Vx Spectra Flowmeter Quantifies Proppant Flowback in Real Time During Post-fracturing Plug Drill Out
  - Advance Flowback in the Power River Basin: Securing Stimulation Investments

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Key Takeaways

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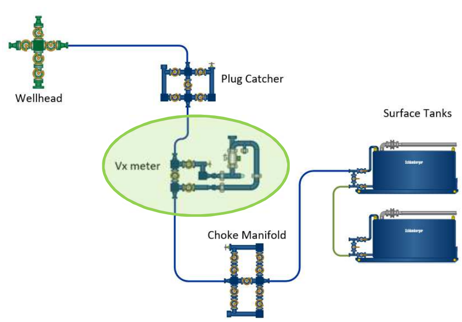
- Modeling supported by Vx MPFM dynamic measurements including solids enable:
  - Efficiently managed well start up operations
  - fracture protection minimizing sand mobilization
  - Enhanced production performance
- Going forward this methodology has the potential to be automated allowing remote operations and less foot print at the well side



Vx Meter Rig up for CT PDO < 5,000 psi

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Questions? Comments?

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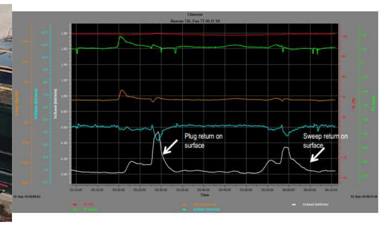
Maintaining Flow control – traditional approach



Maintaining Flow control – A step further

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